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# Diagnostic value of urodynamic study for benign prostatic hyperplasia patients who are considering transurethral surgery: systematic review and meta-analysis

# 수술적 치료를 고려하는 전립선비대증 환자에서의 술 전 요역동학 검사의 진단적 가치: 체계적 문헌고찰 및 메타분석

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# Diagnostic value of urodynamic study for benign prostatic hyperplasia patients who are considering transurethral surgery: systematic review and meta-analysis

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by
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# ABSTRACT

**Purpose:** To investigate the diagnostic value of urodynamic study (UDS) for benign prostatic hyperplasia (BPH) patients who are considering transurethral surgery.

**Methods:** We systematically searched online Pubmed, Embase, and Cochrane Library database from January 1989 to June 2014.

**Results:** A total of 22 articles met the eligibility criteria for this systematic review. The eligible studies included a total of 2,578 patients with a median number of 83 patients per study (range: 12–437). Of the 22 studies, 15 conducted conventional transurethral prostatectomy (TURP), 7 performed the other ore multiple modalities. In patients with urodynamic bladder outlet obstruction (BOO) positive patients, the pooled mean difference (MD) was significant for the better improvement of International Prostatic Symptom Score (IPSS) (pooled MD, 3.48; 95% confidence interval [CI], 1.72–5.24; studies, 16; participants, 1726), quality of life score (QoL) (pooled MD, 0.56; 95% CI, 0.14–1.02; studies, 9; participants, 1052), maximal flow rate (Qmax) (pooled MD, 3.86; 95% CI, 2.17–5.54; studies, 17; participants, 1852), and post-void residual volume (PVR) (pooled MD, 32.46; 95% CI, 23.34–41.58; studies, 10; participants, 1219) compared to non-BOO patients. In patients with detrusor underactivity (DUA), pooled MDs were significant for the poorer improvement of IPSS (pooled MD, −5.83; 95% CI, −7.18–−4.49; studies, 6; participants, 340) and Qmax (pooled MD, −3.86; 95% CI, −4.93–−2.80; studies, 5; participants, 355), but not in that of QoL and PVR. On the other hands, urodynamic detrusor overactivity (DO) did not correlate with improvement of all outcome parameters. Some comparisons showed between-study heterogeneity in spite of strict selection criteria of included studies. However, there was no clear evidence of publication bias in this meta-analysis.

**Conclusions:** Our meta-analysis results showed significant association between urodynamic BOO and better improvements of all parameters of treatment outcomes. Urodynamic DUA was correlated with poorer improvement of IPSS and Qmax. However, urodynamic DO was not associated with surgical outcomes. Preoperative UDS may add insight into postoperative outcomes after surgical treatment of BPH.

**Keywords: benign prostatic hyperplasia; transurethral surgery; surgical outcome; urodynamic study; bladder outlet obstruction; detrusor underactivity; detrusor overactivity**

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# LIST OF ABBREVIATIONS

Benign prostatic hyperplasia (BPH)

Lower urinary tract symptoms (LUTS)

Overactive bladder (OAB)

International prostate symptom store (IPSS)

Quality of life (QoL)

Uroflowmetry (UFM)

Maximal flow rate (Qmax)

Post-void residual volume (PVR)

Urodynamic study (UDS)

Bladder outlet obstruction (BOO)

Bladder outlet obstruction index (BOOI)

Linear passive urethral resistance relation (Lin PURR)

Detrusor underactivity (DUA)

Bladder contractility index (BCI)

Detrusor pressure at the maximal flow rate ($P_{det}Q_{max}$)

Detrusor overactivity (DO)

Involuntary detrusor contraction (IDC)

Transurethral prostatectomy (TURP)

Photoselective vaporization of prostate (PVP)

Transurethral microwave thermotherapy (TUMT)

Interstitial laser coagulation (ILC)

Meta-analysis of observational studies in epidemiology (MOOSE)

Preferred reporting items for systematic reviews and meta-analyses (PRISMA)

Methodological index for non-randomized studies (MINORS)

Level of evidences (LE)

Mean difference (MD)

Standard deviation (SD)

Confidence interval (CI)

# INTRODUCTION

Traditionally, the primary goal of treatment of benign prostatic hyperplasia (BPH) has been to lessen the bothersome lower urinary tract symptoms (LUTS) that caused by prostatic enlargement [1,2]. Surgery is the most invasive option for BPH treatment which can cause irreversible complications [3]. To ensure the better outcome, proper indicators for surgical intervention should be selected. The most recent international treatment guidelines commonly recommend that the surgical intervention should be considered in BPH patients with failure to treat using oral medications or with complicated LUTS [1,2].

The mechanism for surgery is based on the classic bladder outlet obstruction (BOO) model. Enlarged prostate tissue causes obstruction and increases the urethral resistance to flow, therefore requires higher intravesical pressure to void [2]. Urodynamic study (UDS) is the only gold standard for the diagnosis of the BOO [4]. However, invasiveness, cost, and morbidity of UDS limit their clinical use [5]. In these sense, almost guidelines recommend the UDS for male LUTS evaluation in only specific situations such as, prior to surgery, previous unsuccessful treatment, functional cystometric capacity < 150mL, post−void residual urine (PVR) > 300mL, too young (< 50 years) or too old (> 80 years) for surgery [1], relative BOO (maximal flow rate [Qmax] > 10mL/sec) [2] . However, most of those recommendations are supported by very low level of evidences (LEs) (all LE = 3) [1]. To our best knowledge, there have been no randomized studies regarding the usefulness of UDS for guiding clinical application in male LUTS. There are no published randomized controlled trials in men with LUTS which compare the standard investigation such as symptom score or uroflowmetry (UFM) with UDS [1]. Moreover, the utility of performing UDS before transurethral surgery has rarely been studied in a systemic fashion.

Moreover, some specific conditions of bladder such as detrusor underactivity (DUA) or detrusor overactivity (DO) identifiable by the UDS should be considered. Urodynamic DUA is defined as reduced detrusor contraction strength and/or duration resulting in incomplete bladder emptying in the absence of a BOO [6]. When substantial, DUA also results in male LUTS that are indistinguishable from those of BOO [7]. The prevalence of underlying DUA in men with LUTS is known to be approximately 11-40% [1]. Although reduced Qmax on UFM may present as pathognomonic findings of voiding dysfunction, UFM cannot distinguish between DUA and BOO [8]. The UDS including pressure–flow study is only the gold standard for diagnosing underlying DUA. In male LUTS patients who are considering surgery, treatment guidelines recommended that preoperative UDS should be considered to rule out underlying DUA from BOO [1,2], especially when the Qmax is borderline (10-15 mL/sec) [2]. However, evidence is lacking about whether using preoperative UDS to screen for underlying DUA can improve treatment outcomes. Although some researchers reported that DUA may affect surgical outcomes in BPH patients [9,10], these studies were limited by their retrospective designs and conflicting results [9,10].

Meanwhile, DO is defined as a urodynamic observation characterized by involuntary detrusor contraction (IDC) during the filling phase of the UDS [6]. These DO findings are known to be highly correlated with BPH [7,11]. Oelke et al. reported that DO was present in 61% of male patients with LUTS attributed to BPH. They also reported that DO was independently correlated with the degree of BOO and age [7]. Oh et al. reported that DO was frequently observed in patients with BOO than in those without (44.1 vs. 10.3%; p=0.001) [11]. Therefore, it can be deduced that the underlying DO may also be attributed to LUTS in patients with BPH. However, there have been some controversies about whether transurethral surgery resolves urodynamic DO [12,13]. van Venrooij et al. reported that DO was resolved in approximately 50% of patients after transurethral prostatectomy (TURP) [12]. Conversely, another study reported that DO was not improved after the surgery in a long-term UDS follow-up (preoperative vs. follow-up, 40 vs. 64%, p <0.001) [13]. If DO still remained after the surgery, then the symptom improvement might not be satisfactory, because the remaining irritation symptoms could be more prominent in the subgroups of patients. However, it is remains unknown whether preoperative DO is a significant predictor of surgical outcomes in patients with BPH [1,2]. The recent international guidelines also could not confirm the recommendation statements in those specific situations owing to a lack of evidence [1,2].

On these grounds, there is still no established consensus on the effectiveness of surgical intervention in those DUA or DO accompanying subgroups in BPH patients. Guidelines also could not confirmed the recommendation statements in those specific situations due to lack of evidences [1,2]. Because reports about its diagnostic value of UDS in male LUTS are comparatively few, the combination of these data to reach a reasonable conclusion is fairly necessary at present. The objective of the current study was to conduct a systematic review and meta-analysis of published literature investigating the diagnostic value of UDS in male LUTS and to provide higher level of evidence for guiding practical use of UDS in male LUTS.

# MATERIALS AND METHODS

## I. Search strategy for relevant studies

Whole process of this systematic review and meta-analysis were conducted by the preformed study protocol which was confirmed by the authors meeting, and followed the up-dated version of MOOSE and PRISMA recommendations [14,15]. We systematically searched online PubMed, Embase, and Cochrane Library database from their respective inspections until June 2014. Our overall search strategies included terms for UDS (urodynamic, cystometry, and pressure flow study), BPH (benign prostatic hyperplasia, benign prostatic obstruction, and male LUTS), and transurethral surgery (transurethral resection, transurethral incision, vaporization, ablation, and enucleation). Detailed queries for search strategy are presented in Appendix 1. Manual search of relevant studies also performed referring the review article or original research articles of similar subjects.

## II. Selection criteria of eligible studies for meta-analysis

The inclusion criteria for our systematic review were, as follows: ①original research articles published in English; ②subjects comprised of pure BPH patients; ③underwent transurethral surgery for BPH treatment; ④preoperatively sub-grouped by the definite urodynamic criteria of BOO, DUA and DO; ⑤outcome parameters were objectively described using standard investigation tools such as International Prostate Symptom Score (IPSS), or UFM parameters; ⑥the association between preoperative UDS criteria and improvement of treatment outcome was investigated; ⑦size of the sample is provided; and ⑧standard deviation (SD), or confidence interval (CI) or other distributional information of outcome parameters were offered in the paper. When some studies were suspected the duplication of the patient data, the most recently published or most informative single article was selected. If the population of some study underwent 2 or more surgical procedures [16,17], each data were processed separately by the type of surgery. Due to the unavailability of randomized studies, all the non-randomized and retrospective featured studied included to the systematic review and meta-analysis. Exclusion criteria were, as follows: ①studied could not satisfy aforementioned inclusion criteria; ②review articles or letters; ③laboratory studies, such as studies on ex-vivo and animal models; and ④studies which are not providing sufficient data to estimating mean and SD values of improved outcomes.

To minimize the bias, abstracts screening and full text assessment for eligibility were independently performed by all three authors (MK, CWJ, and SJO). All screened abstracts were classified into three categories: ①not-eligible, ②unclear, and ③potentially-eligible. The full texts of "potentially-eligible" and "unclear" studies were obtained and assessed for eligibility. All disagreements among three reviewers were resolved by consensus meeting.

### III. Data extraction and quality assessments

The extracted data elements was, as follows: ①overall characteristics of eligible studies: name of first author, publication year, country, recruitment period, study design, population size, type of surgical intervention, urodynamic standards and cut-off value to diagnosis the BOO, DUA and DO, quality score of each studies; ②characteristics of the patients:

analyzed population size, mean or median age, time of treatment outcome evaluation, compared outcome parameters; ③population sizes of each subgroups when divided by present or absent of BOO, DUA, and DO; and ④mean improved values of IPSS (ΔIPSS), IPSS-QoL (ΔIPSS-QoL), Qmax (ΔQmax), and PVR (ΔPVR) of each subgroup with their SD, after the surgical interventions. Study quality was assessed independently by all three authors using the MINOR criteria (score range: 0-24) [18]. Any disagreement was resolved by discussion.

## IV. Statistical analysis

### 1) Primary analysis

Mainly compared outcome parameters were ΔIPSS, ΔIPSS-QoL, ΔQmax, and ΔPVR of each subgroups divided by presence or absence of urodynamic BOO, DUA, and DO. Due to the continuous parametric feature of outcomes, pooled mean difference (MD) were utilized as summarizing statistics for meta-analysis. A random-effect model was used to obtain the summary pooled MDs and 95% CIs. Mean value and SD of outcome parameters were needed for data integration. For each studies, those values was estimated by a method depending on the data provided in the publications using previously suggested techniques [19,20]. An observed pooled MD > 0 indicated better treatment outcome for the study group (UDS finding positive group) relative to the reference group (UDS finding negative group), and would be considered statistically significant if the 95% CI did not overlap the pooled MD value of zero, with $p < 0.05$.

### 2) Subgroup (sensitivity) analysis

Subsequently, we assessed subgroup analysis with the patients who underwent conventional TURP to evaluate the effect of type of surgery. Due to relatively small number of eligible studies, patients with other subtypes of surgery could not be performed the subgroup analysis. Furthermore, in BOO comparisons, subgroup analysis were performed by the two dominant criteria for BOO diagnosis (BOO index [BOOI] > 40 [21] and linear passive urethral resistance relation [lin PURR] grade ≥ 2, 3 or 4 [22]) to evaluate the effect of diagnostic criteria.

### 3) Assessment of heterogeneity

Heterogeneity was assessed using the heterogeneity x2 test (Cochran's Q−test), with a p value of > 0.05 represent for the absence of significant heterogeneity [23]. The I2 statistic (Higgin's H−test) was performed to visualize degree of heterogeneity [24].

### 4) Publication bias

Possibilities of publication bias were assessed in each comparisons. Funnel plots (Harbord test) of all comparisons were drew to evaluate the bias [25].

### 5) Utilized tools

Review Manager (RevMan) version 5.3 (The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark) was utilized for the meta−analysis.

# RESULTS

A flow chart of whole process on the study selection is shown in Figure 1. Our search strategy identified 3875 articles (PubMed, 1445 articles; Embase, 2137 articles; Cochrane Library database, 293 articles). Additionally, 133 articles were found by manual searching. After duplicates removed, 2611 abstracts were independently screened by three authors. After 2 steps of abstract screening, 223 articles were entered to full text assessment for eligibility. After careful review full articles, 201 were excluded for the following reasons: 23 studies were written by other than English, seven were review articles, one was letter to editor, 15 articles could not obtain the full manuscript, 63 were out of scope, 34 were covered relating subject but could not satisfy the inclusion criteria in detailed methodology, 49 were absent of eligible data, and nine studies were excluded due to the duplication of population. Eventually 22 studies were selected as eligible for the data synthesis [9,10,16,17,26−43].

## Characteristics of included studies

Tables 1 and 2 are showing general characteristics of eligible studies. The 22 eligible studies included a total of 2,578 patients, with a median number of 83 patients per study (range: 12–487). None of selected studies was randomized prospective study. Seven of 22 included studies were non-randomized prospective study, and remains had retrospective feature. Patients received the TURP in 15 of 22 studies [10,26,27,29,30,32–36,38–40,42,43], photoselective vaporization of prostate (PVP) in three studies [9,37,41], transurethral microwave thermotherapy (TUMT) in one study [28], interstitial laser coagulation (ILC) in one study [31], and multiple intervention modalities in two studies [16,17]. The definition of urodynamic BOO varied among studies, whereas those DUA and DO were similar in broad outlines. The cutoff value used to define BOO was BOOI > 40 in nine studies [9,30,33,35,36,40–43], Lin PURR grade ≥ 4 in four studies [17,28,31,39], Lin PURR grade ≥ 3 in four studies [29,32,34,38], Lin PURR grade ≥ 2 in one study [10], and others in four studies [16,26,27,37]. The median quality score measured by MINOR criteria recorded as 16 (range: 14–18). There was no significant correlation between population size and quality scores ($p = 0.470$, by Spearman's correlation analysis) (Table 1). Median or mean ages of study populations were as shown in Table 2. Time of treatment outcome evaluation varied (range: 1–144 months). Mean and SD values of ΔIPSS, ΔIPSS-QoL, ΔQmax, and ΔPVR could be obtained in some studies, whereas could not in others (Table 2). If the mean and SD values could not be obtained, those values are estimated using other representative and distributional values. Details in process are shown in the Table 3.

### BOO positive vs. BOO negative

Forrest plots of the meta-analyses comparing the treatment outcome between urodynamic BOO positive and negative patients are shown in Figure 2. Each figure represents pooled MD and its 95% CI of ΔIPSS (Fig. 2A), ΔIPSS-QoL (Fig. 2B), ΔQmax (Fig. 2C), and ΔPVR (Fig. 2D). In comparisons with BOO present and absent patients, all the pooled mean MD was significantly higher than zero as follows; ΔIPSS (pooled MD, 3.48; 95% CI, 1.72–5.24; studies, 16; participants, 1726; Fig. 2A), ΔIPSS-QoL (pooled MD, 0.56; 95% CI, 0.14–1.02; studies, 9; participants, 1052; Fig. 2B), ΔQmax (pooled MD, 3.86; 95% CI, 2.17−5.54; studies, 17; participants, 1852; Fig. 2C), and ΔPVR (pooled MD, 32.46; 95% CI, 23.34−41.58; studies, 10; participants, 1219; Fig 2D). It means that BOO positive patients have better surgical outcomes in all parameters compared to BOO negative patients.

**DUA positive vs. DUA negative**

Figure 3 is summarizing the result of comparisons between the DUA positive and negative patients. In comparisons with BOO present and absent patients, the pooled mean MD was significantly lower than zero in comparisons of ΔIPSS (pooled MD, −5.83; 95% CI, −7.18−−4.49; studies, 6; participants, 340; Fig. 3A) and ΔQmax (pooled MD, −3.86; 95% CI, −4.93−−2.80; studies, 5; participants, 355; Fig. 3C). In means that DUA positive patients have poorer improvement of IPSS and Qmax compared to DUA negative patients. Whereas, the 95% CI of pooled MD overlapped zero in ΔIPSS−QoL (pooled MD, −0.27; 95% CI, −0.98−0.44; studies, 5; participants, 355; Fig. 3B) and ΔPVR (pooled MD, −7.36; 95% CI, −25.41−10.68; studies, 6; participants, 375; Fig. 3D).

## DO positive vs. DO negative

In comparisons between the DO positive and negative patients (Fig. 4), the 95% CI of pooled MD overlapped zero in all outcome parameters as follows; ΔIPSS (pooled MD, −0.50; 95% CI, −2.21−1.21; studies, 7; participants, 613; Fig. 4A), ΔIPSS−QoL (pooled MD, −0.25; 95% CI, −0.54−0.04; studies, 5; participants, 520; Fig. 4B), ΔQmax (pooled MD, 1.80; 95% CI, −0.39−3.98; studies, 6; participants, 567; Fig. 4C), and ΔPVR (pooled MD, −3.95; 95% CI, −3.82−11.72; studies, 4; participants, 295; Fig 4D). It means that DO positive and negative patients demonstrated no statistical different surgical outcomes after transurethral surgery in BPH patients.

## Subgroup analysis

Subsequently, the subgroup analyses using patients who underwent TURP were performed (Table 4). In patients with TURP, the MDs were also statistically significant in all outcome parameters of BOO comparison and DUA comparison, whereas no significance in all outcome parameters of DO comparison. It was interesting that ΔIPSS−QoL (pooled MD, −0.52; 95% CI, −0.91−−0.13) and ΔPVR (pooled MD, −15.61; 95% CI, −29.43−

−1.80) between DUA positive and negative groups were also significantly different in TURP subgroup. Subgroup analyses of BOO comparisons by the two dominant criteria for BOO diagnosis (BOOI > 40 and lin PURR grade ≥ 2, 3, or 4) were also performed (Table 5). Except for the ΔIPSS−QoL (pooled MD, 0.21; 95% CI, −0.21−0.64) of BOOI subgroup, all pooled MDs of outcome parameters were significantly larger than zero.

## Assessment of heterogeneity and publication bias

Despite of our attempt to limit between−study heterogeneity through strict inclusion and exclusion criteria, heterogeneity between overall treatment outcomes still remained (heterogeneity x2 test: p−values were lower than 0.05 in some comparisons, I2 range: 0%−100%; Figs. 2−4). However, there was no clear evidence of funnel plot asymmetry for outcomes (Figs. 5−8). Therefore it can be concluded that there was no clear evidence of publication bias.

# DISCUSSION

## Choice of appropriate indications for BPH surgery

Surgical treatment for BPH is absolutely indicated when complications (e.g., recurrent retention, hematuria, bladder stone, urinary tract infection, and renal insufficiency) are present [1,2]. However, in real-life practice, patients with complications are few. Instead, almost all patients with BPH are relatively indicated to undergo surgery, and the decision is routinely made on the basis of the clinician's experience. Widely accepted international treatment guidelines are valuable to help clinicians in their decision-making process [1,2]. However, some recommendation statements are not supported by sufficient evidence. In the management of BPH, considering preoperative UDS alone is a typical example of inadequate evidence.

As previously mentioned, guidelines consistently recommend ruling out underlying DUA prior to choosing surgery to ensure better outcomes [1,2]. These recommendations stem from the theological mechanism of surgery for BPH, which is based on the conventional BOO model [2]. However, clinical evidence to prove that BPH alone as an indication for surgery is associated with improved surgical outcomes is insufficient [2]. To our knowledge, despite its importance, this issue has not been studied in a randomized controlled trial or systematic review. On the contrary, a systematic review [44] and an randomized controlled trial [45] have indicated the effectiveness of preoperative UDS in surgery for stress urinary incontinence, another major condition in our field.

### Urodynamic BOO and surgical outcome

There have been very often insufficient evidences on which to base clear statements about 'the right treatment', in spite of a large number of studies have been published over several decades [46]. The preoperative evaluation of BPH patients were clear examples of practice with poor evidences. Recent international guidelines recommend the surgical intervention the decision to perform surgery primarily relies on the physician to decide the best initial treatment on a case-by-case basis according to clinical conditions [1,2]. Poor correlation between the degree of urodynamic BOO and degree of their symptoms are suggested by some researchers [47,48]. Those findings indirectly stand by the uselessness UDS as a preoperative evaluation in transurethral surgery for BPH.

However, if the basic principal of the transurethral surgery are based on classic BOO model, it can be expected that the degree of obstruction affect the treatment outcome. However, there has been not many evidence supporting those [1]. The results of the current study provide higher level of evidences which confirm the utility of performing UDS before transurethral surgery for BPH treatment.

During our survey of literature, we encountered various definitions of the urodynamic findings, especially in "BOO". The definition of BOO is basically methods of analyzing the pressure−flow plots. The one of the major purpose of pressure−flow study is the objective diagnosis weather the urethral resistance to flow is abnormally elevated [49]. For that purpose methods have been developed to quantify pressure−flow plots in terms of one or more numerical parameters

[21,22,50−55]. However, optimum method for BOO diagnosis not yet confirmed [49]. Nevertheless, it seems that there is some degree of reliability on inter−test agreement due to their underlying similarity for diagnosing BOO [56]. Moreover, in our current study, subgroup analyses by the two dominant definition criteria demonstrated consistency except for the ΔIPSS−QoL of BOOI subgroup (Table 5).

### Urodynamic DUA and surgical outcome

DUA has been an important issue in the selection of proper indications for BPH surgery. As mentioned earlier, a substantial proportion of male patients with LUTS has an underlying DUA (11-40%) [13,57]. Ruling out these DUA patients is another suggested important role for preoperative UDS [9]. However, some previous studies reported controversial results regarding the effectiveness of preoperative UDS for ruling out DUA. Javlé et al. [30] reported that treatment failure occurred in 100% of patients without urodynamic BOO after TURP [30]. They concluded that preoperative UDS is helpful for screening patients who would not benefit from surgery. Conversely, Gotoh et al. [32] reported that patients without definite urodynamic

BOO have good outcomes; therefore, these patients can also be considered surgical candidates [32]. The two extremely different conclusions about the usefulness of preoperative UDS seemed to have originated from the different definitions of "treatment success" [30,32]. The former defined "treatment success" as >50% improvement of IPSS and uroflometric parameters [30]; however, the latter defined it as "fair," "good," or "excellent" on a four-question subjective satisfactory questionnaire [32].

This contradictory evidence can act as a barrier to utilizing research evidence in real-life practice [45]. To draw clear conclusions regarding these issues, we performed a systematic review of the effect of preoperative DUA on transurethral surgery outcomes. Considering that the treatment outcomes may depend on the outcome measurement standards, we performed a broad, unbiased literature search with strict criteria for study selection. For the systematic review, standardized methods were applied [14,15]. In the present study, the relationship between preoperative DUA and the treatment outcome parameters was not consistent but still had overall effects favoring the absence of DUA being predictive factor of better postoperative cure (Fig. 3). Moreover, in a sensitivity analysis of the conventional TURP subgroups, all parameters were improved to a greater degree in DUA-negative patients (Table 4). The results of the present study provide a higher level of evidence to confirm the usefulness of performing UDS before transurethral surgery for treating BPH.

Therefore, the DUA-positive group also can experience symptom improvements after BPH surgery. In this study, the improvements in IPSS-QoL and PVR tended to be greater, though without statistical significance, in the DUA-negative group, whereas the improvements in IPSS and Qmax in the DUA-positive group were significantly less than those in the DUA-negative group (Fig. 3). This might be caused by the low statistical power owing to the small sample size, too narrow or wide range of scales or their deviations, or the suboptimal cutoff value of DUA for predicting surgical outcomes (Fig. 3B and 3D). Therefore, the presence of preoperative DUA (defined as BCI of <100 in almost all the eligible studies) might not be an absolute contraindication for surgical treatment in BPH patients.

Owing to the innate nature of the meta-analysis, the optimal cutoff point for surgical decision could not be determined in this study. However, at least physicians and patients should be aware that BPH patients with urodynamic DUA who are considering surgery would have compromised treatment outcomes. Likewise, the proper indication for preoperative UDS is not confirmed by our data. Considering that DUA-positive patients tended to have larger amount of preoperative PVR than the DUA-negative patients (pooled MD, 31.64; 95% CI, −0.36 - 65.7; studies, nine; participants, 968; figure is not shown), preoperative PVR might be a screening tool for deciding preoperative UDS as the guidelines recommended [1,2].

### Urodynamic DO and surgical outcome

Urodynamic DO is also an important issue for the selection of proper indicators for BPH surgery. However, there are also relatively few available studies exploring the significance of preoperative DO in transurethral surgery, and some of them have controversial results [9,10,33,37-39,41]. Our synthesized data demonstrated that urodynamic DO was not correlated with all postoperative outcome parameters (Fig. 4).

In the guidelines, the diagnostic role of preoperative DO for stratifying the indicators for surgery in BPH is not yet confirmed [1,2]. To draw clear conclusions, prospective randomized controlled trials on the value of preoperative UDS are urgently needed, as in other diseases [45]. Unfortunately, there has been no published randomized controlled trial on BPH as aforementioned [1]. In these situations, the results of the current study are important because these may be the highest-level evidences in existence.

Preoperative DO showed no correlation with the degrees of improvement in surgical outcomes (Fig. 4). Some factors can explain those findings. First, the DO findings in male patients with LUTS could have originated from various causes. Preoperative DO can imply the predisposing of the underlying overactive bladder (OAB) and their attribution to LUTS [58]. However, those DO findings also suggest the secondary accommodation of bladder steaming from severe BOO [7,11]. Therefore, male patients with LUTS who are urodynamic DO positive can be presumed to have an independently accompanying OAB or long-standing severe BOO. If the preoperative DO findings of patients indirectly indicate the presence of severe BOO, those patients can also be expected to have the better improvements in symptoms. It can be postulated that those features of DO can be counterbalanced by the effect of residual OAB symptoms after the surgery.

Second, in addition to DO being an urodynamic diagnostic criterion, OAB is diagnosed based on the prevalence of urgency, usually with frequency and nocturia1. Therefore, the terms OAB and DO are not interchangeable because 21% of patients with urgency do not have urodynamic DO [58]. Moreover, Hyman et al. also reported that DO was positive in only 44% of male patients with urgency or frequency, and negative in ≥25% of patients with urge incontinence [59]. The discordances between urodynamic findings and actual symptoms can also be another reason for preoperative DO being a poor predictor of surgical outcomes in patients with BPH.

**Limitations and strengths of the current study**

However, our recent study has some limitations. First of all, none of the studies included in the current meta-analysis specified a prospective design. To our best knowledge, there has been no randomized study regarding the usefulness of UDS for guiding clinical management in male LUTS [1]. This may be due to complexity for the design of the study in prospective feature. It is difficult to draw any conformational conclusions when studies are not conducted prospectively. Thus, the results of our current study are important because, they can provide a higher LE regarding the diagnostic value of preoperative UDS in male LUTS patients who are considering transurethral surgery. The results of our study also can be an important reference for design of further prospective study in the future.

Second, due to the unavailability of mean and variance (or SD) in some studies, those values are estimated using other presented distributional parameters for the outcome synthesis (see Table 3). This can lead to some errors used in the estimation processes. However, the data imputation technique which were used in this study were verified the low possibility of statistical errors in previous study [60]. For the clarification of these points, accumulation of more evidence is needed.

Third, in our current meta-analysis, there was some heterogeneity for included studies (Figs. 2-4). Heterogeneity can be caused by numerous factors, such as inclusion criteria, type of surgery, sample size, period of postoperative outcome evaluation, urodynamic cutoff values, and adjustment for other co-factors. It is also very difficult to explain inter-study heterogeneity, due to the variability in clinical characteristics across patients within studies. To lessen the heterogeneity related bias, we adopted the random-effect model for data synthesis, which is known to be to draw more conservative results [20]. All subgroup analyses also showed consistency with main results (Tables 4 and 5). Moreover, the direct evidences of publication bias were not shown (Figs. 5-7).

Lastly, the BOO negative or DUA positive group also can experience symptom improvements from BPH surgery, although the degree of improvement in the BOO negative/DUA positive group is significantly less than that in the BOO positive/ DUA negative group (Fig. 2 and 3). Therefore, those cut-off values (BOOI > 40 or BCI > 100) might not be an absolute indication for surgical treatment in patients with BPH. This indicates that urodynamic BOO positive/DUA negative patients with BPH who are considering surgery would have better treatment outcomes than BOO negative/DUA positive patients. However, being BOO/DUA positive (or negative) is not an absolute indication that the patient should (or should not) receive the surgery.

Despite the some limitations, the findings from the present study suggest that preoperative urodynamic BOO and DUA have their diagnostic role for predicting treatment outcomes of surgery in male LUTS patients. The strength of the currents study are as follows; ①broad, unbiased search of the literature; ②strict criteria for study selection; ③application of standardized methods for systematic review [14,15].

# CONCLUSIONS

In conclusion, our meta-analysis results demonstrated significant association between preoperative BOO positive and better improvement of surgical outcomes including IPSS, IPSS-QoL, Qmax, and PVR. Preoperative urodynamic DUA positive was significantly associated with poorer improvement of IPSS and Qmax, and poorer tendency, but not statistically significant, in improvement of IPSS-QoL and PVR. On the other hands, preoperative urodynamic DO was not correlated with treatment improvement in all outcome parameters. On these grounds, preoperative urodynamic BOO and DUA are seemed to have their diagnostic role for predicting treatment outcomes of surgery in male LUTS patients. However, the diagnostic value of UDS for preoperative evaluation also needs to be confirmed in controlled trials before any definitive conclusions can be made.

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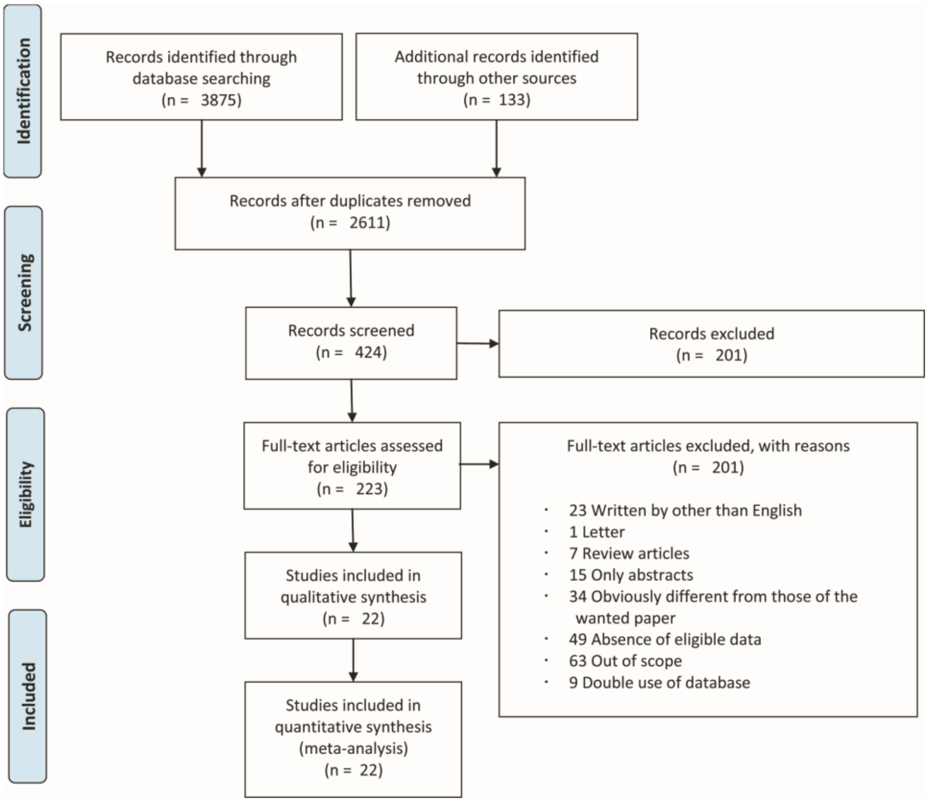


Figure 1. Methodological flow chart of the systematic review

## A. Improvement of IPSS

| Study or Subgroup | BOO positive Mean | SD | Total | BOO negative Mean | SD | Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| De la Rosette 1996 | 11.3 | 7.7 | 52 | 8.4 | 8.4 | 68 | 6.0% | 2.90 [0.01, 5.79] |
| Ignjatovic 1997 | 15.5 | 5.7 | 24 | 5 | 2 | 24 | 6.3% | 10.50 [8.08, 12.92] |
| Witjes 1997 (Laser) | 13.8 | 11.4 | 47 | 16.3 | 6.6 | 36 | 5.3% | -2.50 [-6.41, 1.41] |
| Witjes 1997 (TUMT) | 11.3 | 9.6 | 58 | 7.6 | 10.3 | 78 | 5.7% | 3.70 [0.33, 7.07] |
| Javlé 1998 | 14.8 | 5.5 | 27 | 9.5 | 6.2 | 26 | 5.8% | 5.30 [2.14, 8.46] |
| Dæhlin 1999 | 7.5 | 8.9 | 10 | 14.5 | 6.7 | 14 | 3.6% | -7.00 [-13.54, -0.46] |
| Machino 2002 | 11.9 | 7.2 | 33 | 11.2 | 6.3 | 27 | 5.6% | 0.70 [-2.72, 4.12] |
| Porru 2002 | 12.9 | 5.5 | 37 | 1.3 | 5 | 8 | 5.3% | 11.60 [7.71, 15.49] |
| Hakenberg 2003 | 10.5 | 6.9 | 46 | 8.6 | 9.8 | 30 | 5.2% | 1.90 [-2.13, 5.93] |
| Van Venrooij 2003 | 15 | 4 | 59 | 9.1 | 2.8 | 34 | 6.8% | 5.90 [4.51, 7.29] |
| Seki 2006 | 10.1 | 7.5 | 112 | 10.4 | 7.2 | 78 | 6.5% | -0.30 [-2.42, 1.82] |
| Tanaka 2006 | 16.6 | 9.3 | 17 | 11.1 | 7.4 | 75 | 4.7% | 5.50 [0.77, 10.23] |
| Vesely 2006 (TURP) | 10.3 | 7.2 | 66 | 10.3 | 6.8 | 14 | 5.2% | 0.00 [-3.96, 3.96] |
| Vesely 2006 (TUMT) | 11.9 | 7 | 20 | 6.5 | 7.9 | 82 | 5.6% | 5.40 [1.89, 8.91] |
| Han 2008 | 13.3 | 7.8 | 46 | 8.7 | 9 | 25 | 5.1% | 4.60 [0.41, 8.79] |
| Masumori 2010 | 16 | 7.5 | 18 | 8.6 | 7.5 | 16 | 4.5% | 7.40 [2.35, 12.45] |
| Oh 2012 | 14.4 | 6.4 | 80 | 12.9 | 6.9 | 54 | 6.3% | 1.50 [-0.81, 3.81] |
| Min 2013 | 14.4 | 7.4 | 161 | 12 | 8 | 124 | 6.6% | 2.40 [0.59, 4.21] |
| **Total (95% CI)** | | | **913** | | | **813** | **100.0%** | **3.48 [1.72, 5.24]** |

Heterogeneity: $Tau^2 = 11.34$; $Chi^2 = 106.85$, df = 17 ($P < 0.00001$); $I^2 = 84\%$
Test for overall effect: Z = 3.87 (P = 0.0001)

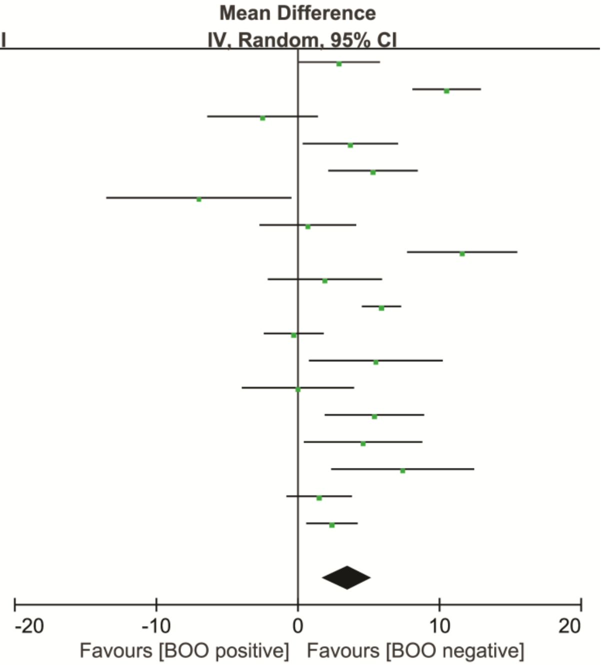


Figure 2. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without bladder outlet obstruction (BOO) using random effects model. (A) Improvement of IPSS

## B. Improvement of QoL score

| | BOO positive | | | BOO negative | | | | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| **Study or Subgroup** | **Mean** | **SD** | **Total** | **Mean** | **SD** | **Total** | **Weight** | **IV, Random, 95% CI** |
| Machino 2002 | 2.9 | 1.2 | 33 | 3.5 | 1.3 | 27 | 10.0% | -0.60 [-1.24, 0.04] |
| Porru 2002 | 3 | 1.1 | 37 | 0 | 1.1 | 8 | 8.6% | 3.00 [2.16, 3.84] |
| Van Venrooij 2003 | 3 | 0.7 | 59 | 2.5 | 1 | 34 | 11.6% | 0.50 [0.12, 0.88] |
| Seki 2006 | 2.3 | 1.4 | 112 | 2.2 | 1.4 | 78 | 11.4% | 0.10 [-0.30, 0.50] |
| Tanaka 2006 | 3.4 | 1.1 | 17 | 2.8 | 1.4 | 75 | 10.2% | 0.60 [-0.01, 1.21] |
| Vesely 2006 (TURP) | 2.1 | 1.5 | 66 | 1.9 | 1.3 | 14 | 9.1% | 0.20 [-0.57, 0.97] |
| Vesely 2006 (TUMT) | 2.2 | 1.5 | 20 | 1.7 | 1.5 | 82 | 9.4% | 0.50 [-0.23, 1.23] |
| Han 2008 | 2.7 | 1.4 | 46 | 2.2 | 1.3 | 25 | 9.9% | 0.50 [-0.15, 1.15] |
| Masumori 2010 | 3.7 | 0.9 | 18 | 2.5 | 1.6 | 16 | 8.3% | 1.20 [0.31, 2.09] |
| Min 2013 | 2.9 | 1.6 | 161 | 2.6 | 1.7 | 124 | 11.5% | 0.30 [-0.09, 0.69] |
| **Total (95% CI)** | | | **569** | | | **483** | **100.0%** | **0.58 [0.14, 1.02]** |

Heterogeneity: $Tau^2 = 0.40$; $Chi^2 = 52.62$, $df = 9$ ($P < 0.00001$); $I^2 = 83\%$
Test for overall effect: $Z = 2.58$ ($P = 0.010$)

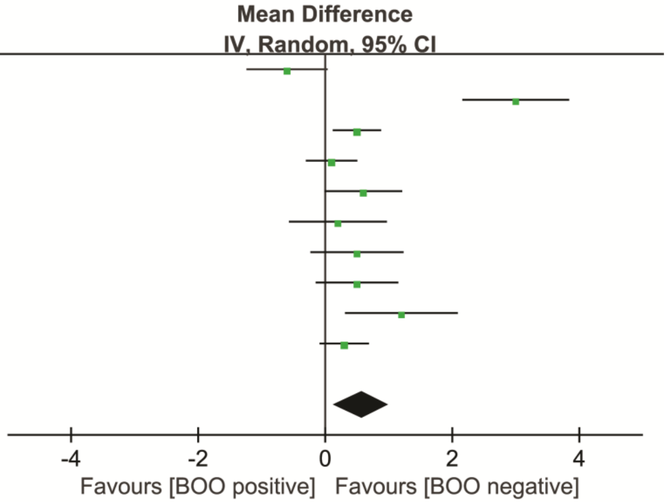


Figure 2. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without bladder outlet obstruction (BOO) using random effects model. (B) Improvement of QoL Score

## C. Improvement of Qmax

| Study or Subgroup | BOO positive Mean | SD | Total | BOO negative Mean | SD | Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Schäfer 1989 | 16.1 | 3.2 | 20 | 2.2 | 2.6 | 19 | 5.8% | 13.90 [12.07, 15.73] |
| Gormley 1993 | 12.3 | 13 | 9 | 4 | 10.6 | 3 | 1.1% | 8.30 [-6.40, 23.00] |
| De la Rosette 1996 | 7 | 7.3 | 52 | 2.9 | 5.2 | 68 | 5.5% | 4.10 [1.76, 6.44] |
| Witjes 1997 (TURP) | 9.4 | 10.8 | 44 | 7.9 | 9.2 | 43 | 4.5% | 1.50 [-2.71, 5.71] |
| Witjes 1997 (Laser) | 12.9 | 6.3 | 47 | 12.1 | 5.3 | 36 | 5.5% | 0.80 [-1.70, 3.30] |
| Witjes 1997 (TUMT) | 6.6 | 7 | 58 | 2.7 | 5 | 78 | 5.7% | 3.90 [1.78, 6.02] |
| Javlé 1998 | 9.2 | 3.5 | 27 | 4.4 | 3.7 | 26 | 5.7% | 4.80 [2.86, 6.74] |
| Dæhlin 1999 | 1.6 | 2.4 | 10 | 2 | 3.7 | 14 | 5.5% | -0.40 [-2.84, 2.04] |
| Gotoh 1999 | 10.2 | 6 | 52 | 7.2 | 4 | 22 | 5.5% | 3.00 [0.66, 5.34] |
| Machino 2002 | 8.8 | 6 | 31 | 8 | 6.5 | 25 | 5.0% | 0.80 [-2.51, 4.11] |
| Porru 2002 | 12.2 | 7.4 | 37 | 2.3 | 4.4 | 8 | 4.7% | 9.90 [6.03, 13.77] |
| Hakenberg 2003 | 9.6 | 11.7 | 46 | 1.6 | 9.5 | 30 | 4.1% | 8.00 [3.21, 12.79] |
| Van Venrooij 2003 | 12 | 4 | 59 | 7.3 | 3.6 | 34 | 5.9% | 4.70 [3.12, 6.28] |
| Seki 2006 | 6.5 | 5.7 | 112 | 4.4 | 5.9 | 78 | 5.8% | 2.10 [0.42, 3.78] |
| Tanaka 2006 | 11.8 | 6.9 | 17 | 9.7 | 8.4 | 75 | 4.7% | 2.10 [-1.69, 5.89] |
| Vesely 2006 (TURP) | 5.5 | 7.8 | 66 | 3.8 | 9.9 | 14 | 3.7% | 1.70 [-3.82, 7.22] |
| Vesely 2006 (TUMT) | 2.6 | 7.2 | 20 | 1.5 | 6.5 | 82 | 4.9% | 1.10 [-2.35, 4.55] |
| Han 2008 | 6.3 | 8.6 | 46 | 2.1 | 7.6 | 25 | 4.7% | 4.20 [0.32, 8.08] |
| Oh 2012 | 8.5 | 5.4 | 80 | 5.3 | 5.4 | 54 | 5.8% | 3.20 [1.34, 5.06] |
| Min 2013 | 7.8 | 7.2 | 161 | 5.2 | 6.8 | 124 | 5.9% | 2.60 [0.97, 4.23] |
| **Total (95% CI)** | | | **994** | | | **858** | **100.0%** | **3.86 [2.17, 5.54]** |

Heterogeneity: $Tau^2 = 11.90$; $Chi^2 = 163.37$, $df = 19$ ($P < 0.00001$); $I^2 = 88\%$

Test for overall effect: $Z = 4.49$ ($P < 0.00001$)

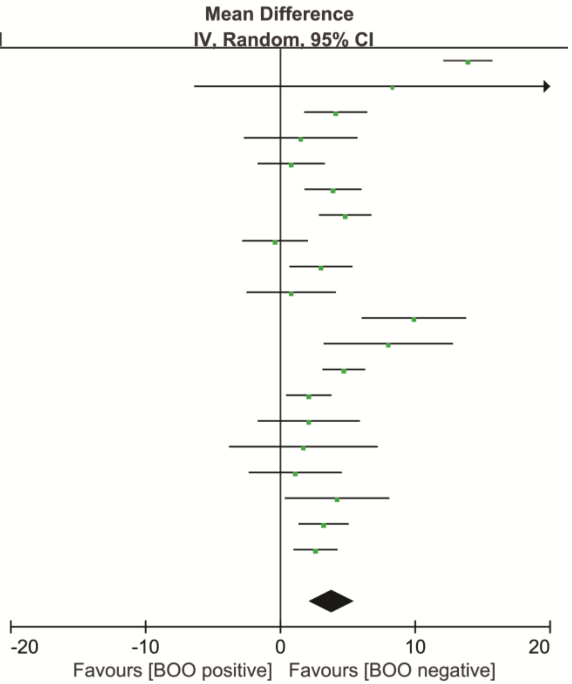


Figure 2. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without bladder outlet obstruction (BOO) using random effects model. (C) Improvement of Qmax

## D. Improvement of PVR

| Study or Subgroup | BOO positive Mean | SD | Total | BOO negative Mean | SD | Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| De la Rosette 1996 | 51 | 110 | 52 | 34 | 104.5 | 68 | 5.1% | 17.00 [-21.87, 55.87] |
| Witjes 1997 (TURP) | 121 | 150 | 44 | 57.9 | 95 | 43 | 2.9% | 63.10 [10.46, 115.74] |
| Witjes 1997 (Laser) | 100 | 88 | 47 | 42.1 | 70.3 | 36 | 6.5% | 57.90 [23.84, 91.96] |
| Witjes 1997 (TUMT) | 43 | 125 | 58 | 36 | 100.2 | 78 | 5.1% | 7.00 [-32.11, 46.11] |
| Javlé 1998 | 77.2 | 45 | 27 | 39.4 | 34.8 | 26 | 14.3% | 37.80 [16.19, 59.41] |
| Gotoh 1999 | 42.4 | 62.9 | 52 | 47.5 | 94.8 | 22 | 4.2% | -5.10 [-48.25, 38.05] |
| Machino 2002 | 42.8 | 88.8 | 21 | 15 | 45.2 | 18 | 4.2% | 27.80 [-15.54, 71.14] |
| Porru 2002 | 61 | 21.1 | 37 | 21 | 20.9 | 8 | 22.4% | 40.00 [24.00, 56.00] |
| Tanaka 2006 | 79.4 | 77.7 | 17 | 26 | 49 | 75 | 5.2% | 53.40 [14.84, 91.96] |
| Han 2008 | 87.3 | 121.4 | 46 | 93 | 160.8 | 25 | 1.6% | -5.70 [-77.84, 66.44] |
| Oh 2012 | 45.5 | 81.6 | 80 | 18.8 | 70.6 | 54 | 10.5% | 26.70 [0.73, 52.67] |
| Min 2013 | 61.5 | 82.8 | 161 | 34.7 | 76.4 | 124 | 18.1% | 26.80 [8.24, 45.36] |
| **Total (95% CI)** | | | **642** | | | **577** | **100.0%** | **32.46 [23.34, 41.58]** |

Heterogeneity: $Tau^2 = 30.15$; $Chi^2 = 12.47$, $df = 11$ ($P = 0.33$); $I^2 = 12\%$
Test for overall effect: $Z = 6.97$ ($P < 0.00001$)

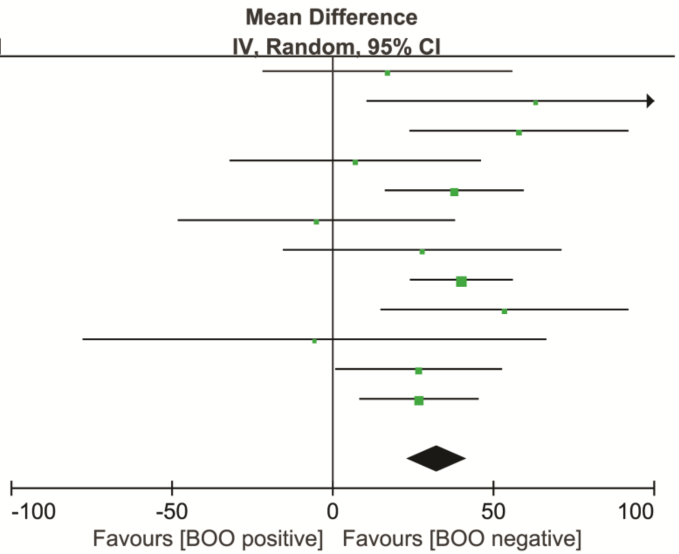


Figure 2. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without bladder outlet obstruction (BOO) using random effects model. (D) Improvement of PVR

## A. Improvement of IPSS

| Study or Subgroup | DUA positive Mean | DUA positive SD | DUA positive Total | DUA negative Mean | DUA negative SD | DUA negative Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Javlé 1998 | 9 | 5.4 | 22 | 16.8 | 6.5 | 28 | 16.6% | -7.80 [-11.10, -4.50] |
| Monoski 2006 | -3.2 | 8 | 2 | 7.8 | 7.5 | 23 | 1.4% | -11.00 [-22.50, 0.50] |
| Tanaka 2006 | 10.1 | 7.6 | 37 | 13.5 | 8.3 | 55 | 16.7% | -3.40 [-6.69, -0.11] |
| Paick 2007 | 5.6 | 3.2 | 34 | 11.5 | 5.1 | 34 | 44.0% | -5.90 [-7.92, -3.88] |
| Han 2008 | 8.7 | 9 | 25 | 13.3 | 7.8 | 46 | 10.3% | -4.60 [-8.79, -0.41] |
| Masumori 2010 | 8.1 | 6.6 | 12 | 14.9 | 3.7 | 22 | 11.0% | -6.80 [-10.84, -2.76] |
| **Total (95% CI)** | | | **132** | | | **208** | **100.0%** | **-5.83 [-7.18, -4.49]** |

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 4.80$, $df = 5$ ($P = 0.44$); $I^2 = 0\%$
Test for overall effect: $Z = 8.51$ ($P < 0.00001$)

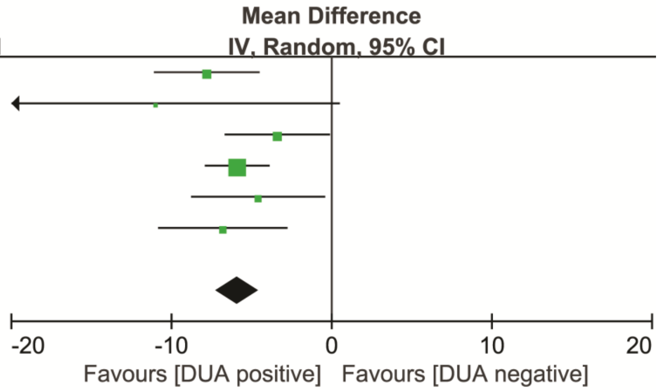


Figure 3. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without detrusor underactivity (DUA) using random effects model. (A) Improvement of IPSS

## B. Improvement of QoL score

| Study or Subgroup | DUA positive Mean | SD | Total | DUA negative Mean | SD | Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Tanaka 2006 | 2.6 | 1.4 | 37 | 3 | 1.2 | 55 | 26.2% | -0.40 [-0.95, 0.15] |
| Paick 2007 | 2.5 | 0.6 | 34 | 2 | 0.4 | 34 | 30.1% | 0.50 [0.26, 0.74] |
| Han 2008 | 2.2 | 1.3 | 25 | 2.7 | 1.4 | 46 | 24.7% | -0.50 [-1.15, 0.15] |
| Masumori 2010 | 2.5 | 1.6 | 12 | 3.5 | 1.1 | 22 | 19.0% | -1.00 [-2.02, 0.02] |
| **Total (95% CI)** | | | **108** | | | **157** | **100.0%** | **-0.27 [-0.98, 0.44]** |

Heterogeneity: $Tau^2 = 0.42$; $Chi^2 = 20.23$, $df = 3$ ($P = 0.0002$); $I^2 = 85\%$

Test for overall effect: $Z = 0.74$ ($P = 0.46$)

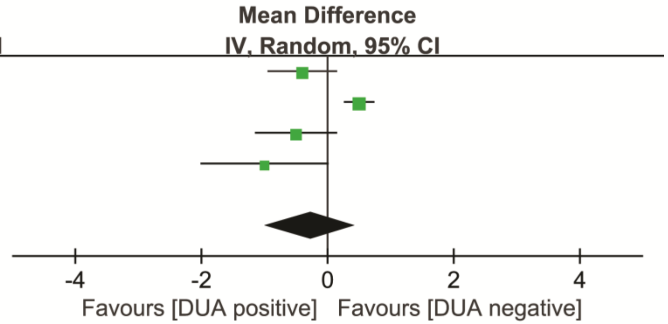


Figure 3. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without detrusor underactivity (DUA) using random effects model. (B) Improvement of QoL Score

**C. Improvement of Qmax**

| Study or Subgroup | DUA positive Mean | SD | Total | DUA negative Mean | SD | Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Javlé 1998 | 4.5 | 3.4 | 22 | 9.9 | 4.6 | 28 | 23.0% | -5.40 [-7.62, -3.18] |
| Gotoh 1999 | 7.9 | 5.3 | 35 | 10.6 | 5.6 | 39 | 18.4% | -2.70 [-5.18, -0.22] |
| Tanaka 2006 | 8.1 | 6.6 | 37 | 11.4 | 8.9 | 55 | 11.3% | -3.30 [-6.47, -0.13] |
| Paick 2007 | 4.4 | 3.4 | 34 | 8 | 3.7 | 34 | 39.8% | -3.60 [-5.29, -1.91] |
| Han 2008 | 2.1 | 7.6 | 25 | 6.3 | 8.6 | 46 | 7.5% | -4.20 [-8.08, -0.32] |
| **Total (95% CI)** | | | **153** | | | **202** | **100.0%** | **-3.86 [-4.93, -2.80]** |

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.93$, df = 4 (P = 0.57); $I^2 = 0\%$

Test for overall effect: Z = 7.11 (P < 0.00001)

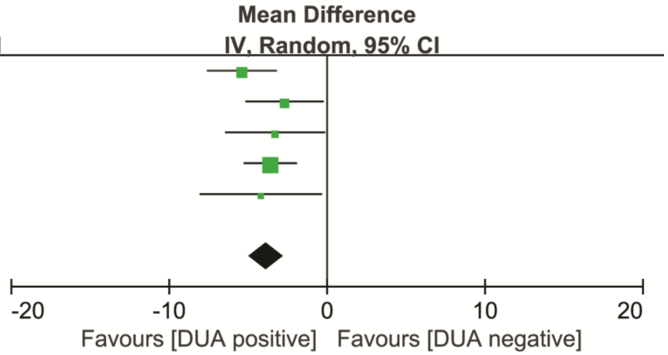


Figure 3. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without detrusor underactivity (DUA) using random effects model. (C) Improvement of Qmax

**D. Improvement of PVR**

| Study or Subgroup | DUA positive Mean | DUA positive SD | DUA positive Total | DUA negative Mean | DUA negative SD | DUA negative Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Javlé 1998 | 27.9 | 28 | 22 | 45.4 | 52.2 | 28 | 23.0% | -17.50 [-40.10, 5.10] |
| Gotoh 1999 | 43.9 | 77.1 | 35 | 44 | 70.8 | 39 | 15.9% | -0.10 [-33.96, 33.76] |
| Monoski 2006 | 592.4 | 288.9 | 3 | 125.8 | 255.2 | 17 | 0.3% | 466.60 [117.90, 815.30] |
| Tanaka 2006 | 22.8 | 32.7 | 37 | 44.7 | 69.8 | 55 | 24.0% | -21.90 [-43.14, -0.66] |
| Paick 2007 | 17.5 | 28.8 | 34 | 16.3 | 16.3 | 34 | 31.6% | 1.20 [-9.92, 12.32] |
| Han 2008 | 93 | 160.8 | 25 | 87.3 | 121.4 | 46 | 5.3% | 5.70 [-66.44, 77.84] |
| **Total (95% CI)** | | | **156** | | | **219** | **100.0%** | **-7.36 [-25.41, 10.68]** |

Heterogeneity: Tau² = 235.96; Chi² = 11.99, df = 5 (P = 0.03); I² = 58%

Test for overall effect: Z = 0.80 (P = 0.42)

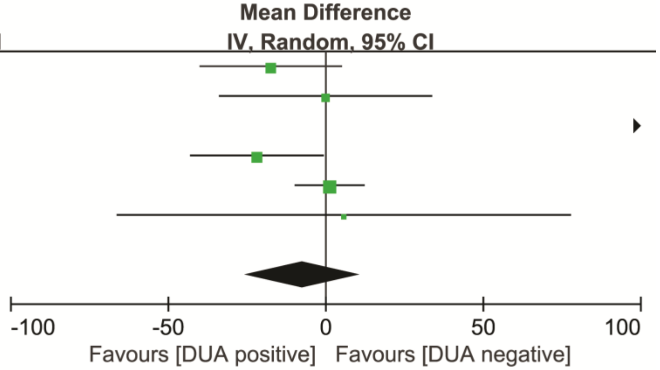


Figure 3. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without detrusor underactivity (DUA) using random effects model. (D) Improvement of PVR

## A. Improvement of IPSS

| Study or Subgroup | DO positive Mean | DO positive SD | DO positive Total | DO negative Mean | DO negative SD | DO negative Total | Weight | Mean Difference IV, Random, 95% CI | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|---|
| Machino 2002 | 11.1 | 7.4 | 27 | 12.3 | 6.1 | 33 | 12.6% | -1.20 [-4.68, 2.28] | |
| Monoski 2006 | 5.8 | 8.3 | 17 | 8.6 | 5.7 | 8 | 6.9% | -2.80 [-8.38, 2.78] | |
| Seki 2006 | 7.8 | 7.7 | 61 | 10.9 | 7.1 | 129 | 18.0% | -3.10 [-5.39, -0.81] | |
| Tanaka 2006 | 12.7 | 8.6 | 44 | 11.6 | 7.9 | 48 | 13.0% | 1.10 [-2.28, 4.48] | |
| Paick 2007 | 8.5 | 3.4 | 25 | 10 | 4.7 | 43 | 19.8% | -1.50 [-3.44, 0.44] | |
| Cho 2010 | 7.4 | 3.6 | 36 | 6.2 | 3.9 | 108 | 22.6% | 1.20 [-0.19, 2.59] | |
| Masumori 2010 | 14.9 | 8.3 | 14 | 10.9 | 7.6 | 20 | 7.1% | 4.00 [-1.48, 9.48] | |
| **Total (95% CI)** | | | **224** | | | **389** | **100.0%** | **-0.50 [-2.21, 1.21]** | |

Heterogeneity: $Tau^2 = 2.87$; $Chi^2 = 15.77$, df = 6 (P = 0.02); $I^2 = 62\%$

Test for overall effect: Z = 0.57 (P = 0.57)

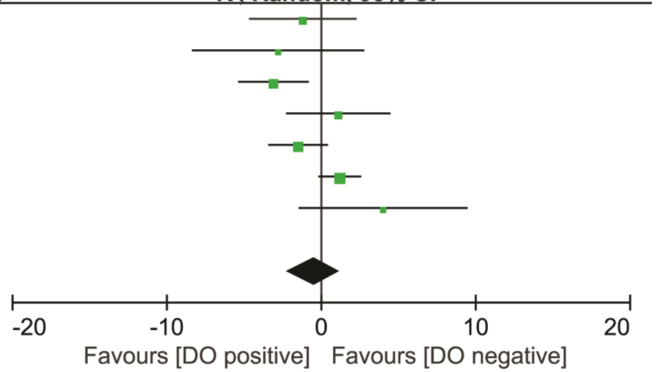


Figure 4. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without detrusor overactivity (DO) using random effects model. (A) Improvement of IPSS

## B. Improvement of QoL score

| | DO positive | | | DO negative | | | | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | IV, Random, 95% CI |
| Machino 2002 | 3.1 | 1.2 | 27 | 3.2 | 1.3 | 33 | 14.8% | -0.10 [-0.73, 0.53] |
| Seki 2006 | 1.9 | 1.5 | 61 | 2.6 | 1.3 | 129 | 23.4% | -0.70 [-1.14, -0.26] |
| Tanaka 2006 | 2.9 | 1.3 | 44 | 2.8 | 1.4 | 48 | 17.9% | 0.10 [-0.45, 0.65] |
| Cho 2010 | 1.2 | 0.6 | 36 | 1.5 | 1 | 108 | 34.9% | -0.30 [-0.57, -0.03] |
| Masumori 2010 | 3.3 | 1.2 | 14 | 3.1 | 1.4 | 20 | 9.0% | 0.20 [-0.68, 1.08] |
| **Total (95% CI)** | | | **182** | | | **338** | **100.0%** | **-0.25 [-0.54, 0.04]** |

Heterogeneity: $Tau^2 = 0.04$; $Chi^2 = 6.83$, $df = 4$ ($P = 0.15$); $I^2 = 41\%$
Test for overall effect: $Z = 1.68$ ($P = 0.09$)

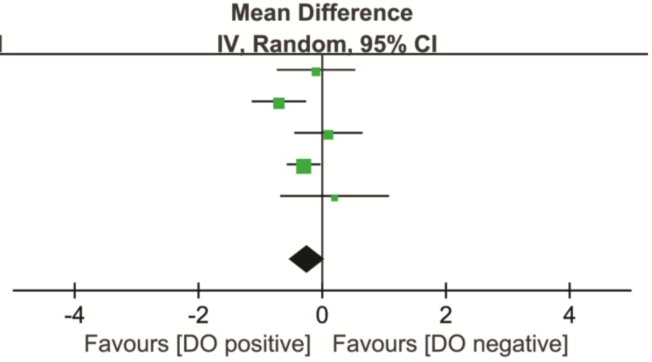


Figure 4. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without detrusor overactivity (DO) using random effects model. (B) Improvement of QoL Score

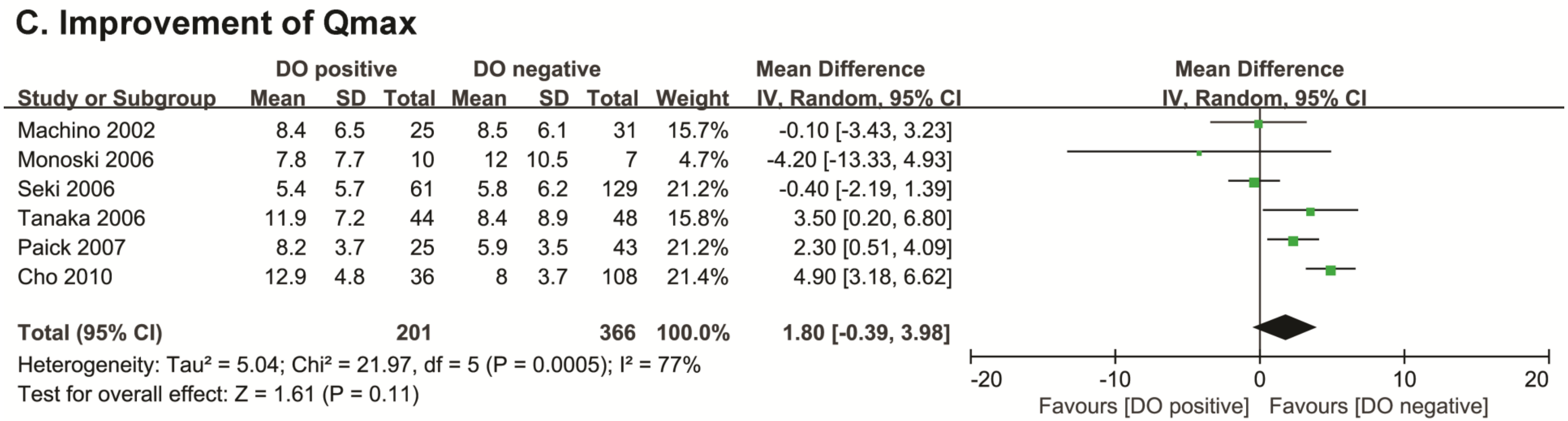


Figure 4. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without detrusor overactivity (DO) using random effects model. (C) Improvement of Qmax

## D. Improvement of PVR

| | DO positive | | | DO negative | | | | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | IV, Random, 95% CI |
| Machino 2002 | 35 | 95.8 | 12 | 20.4 | 46.7 | 27 | 1.9% | 14.60 [-42.39, 71.59] |
| Monoski 2006 | 154.4 | 299.3 | 14 | 253.8 | 443.3 | 6 | 0.0% | -99.40 [-487.21, 288.41] |
| Tanaka 2006 | 41.2 | 65.7 | 44 | 28.9 | 51.5 | 48 | 10.2% | 12.30 [-11.97, 36.57] |
| Cho 2010 | 36.3 | 22.4 | 36 | 33.5 | 20.6 | 108 | 87.9% | 2.80 [-5.48, 11.08] |
| **Total (95% CI)** | | | **106** | | | **189** | **100.0%** | **3.95 [-3.82, 11.72]** |

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.94$, df = 3 (P = 0.82); $I^2 = 0\%$

Test for overall effect: Z = 1.00 (P = 0.32)

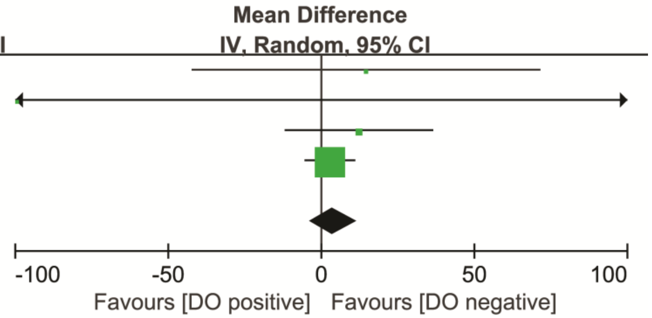


Figure 4. Forest plots comparing improvement of outcome parameters after the transurethral surgery with or without detrusor overactivity (DO) using random effects model. (D) Improvement of PVR

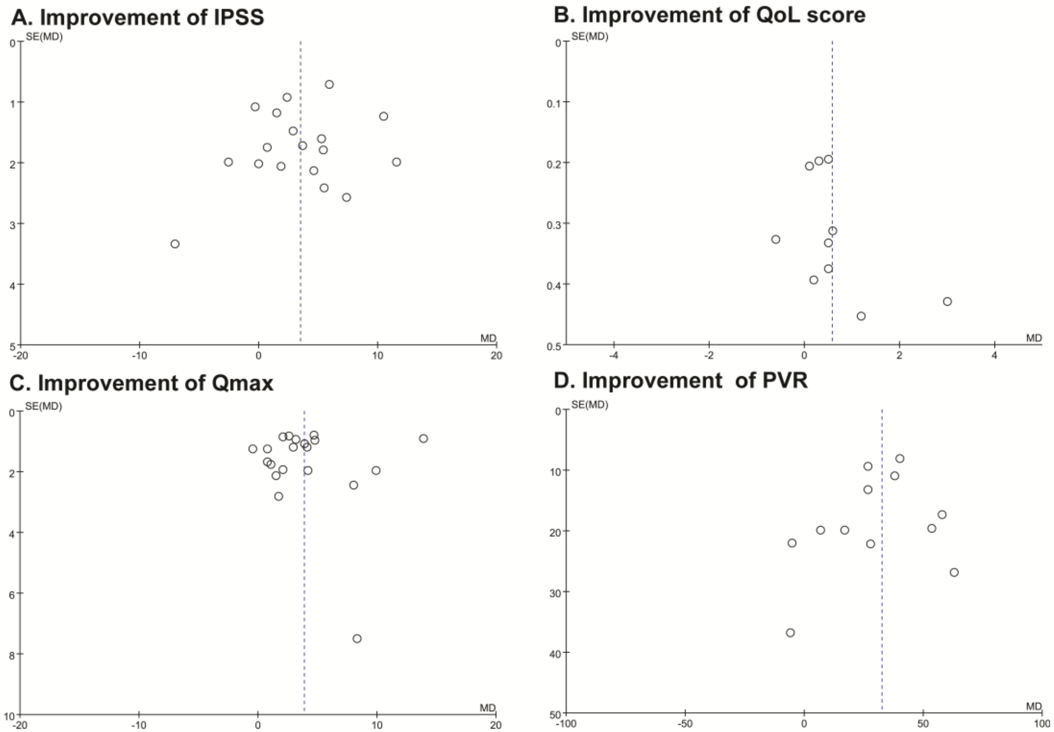


Figure 5. Funnel graphs of the assessment of potential publication bias in studies of comparing improvement of outcome parameters after the transurethral surgery with or without bladder outlet obstruction (BOO)

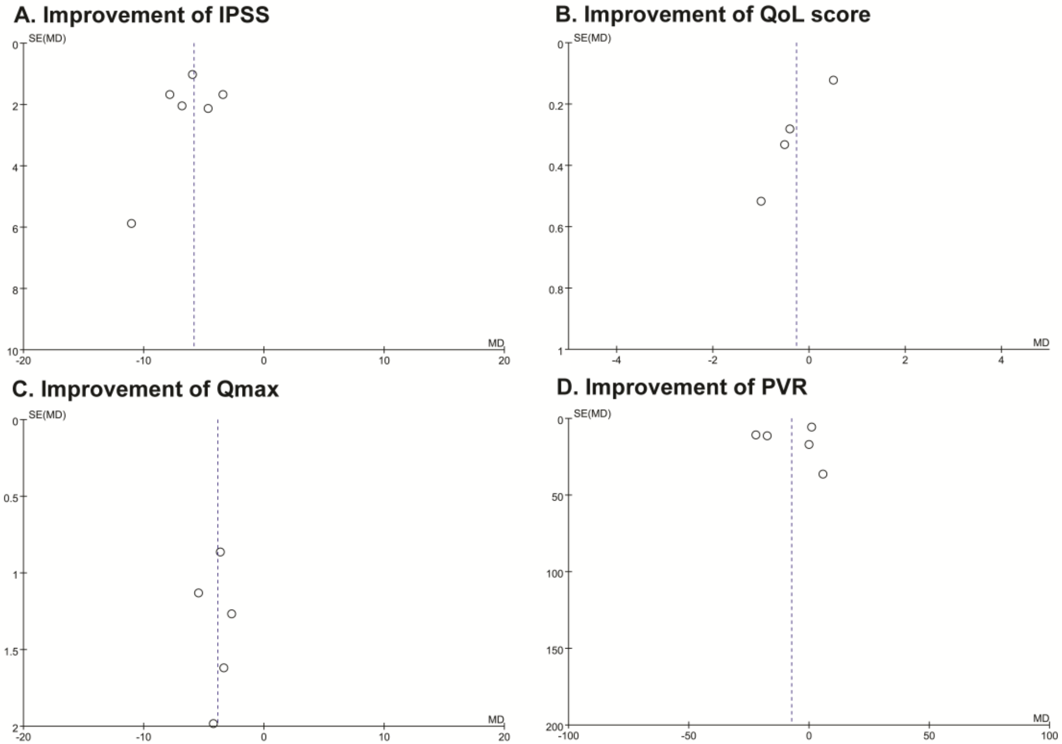


Figure 6. Funnel graphs of the assessment of potential publication bias in studies of comparing improvement of outcome parameters after the transurethral surgery with or without detrusor underactivity (DUA)

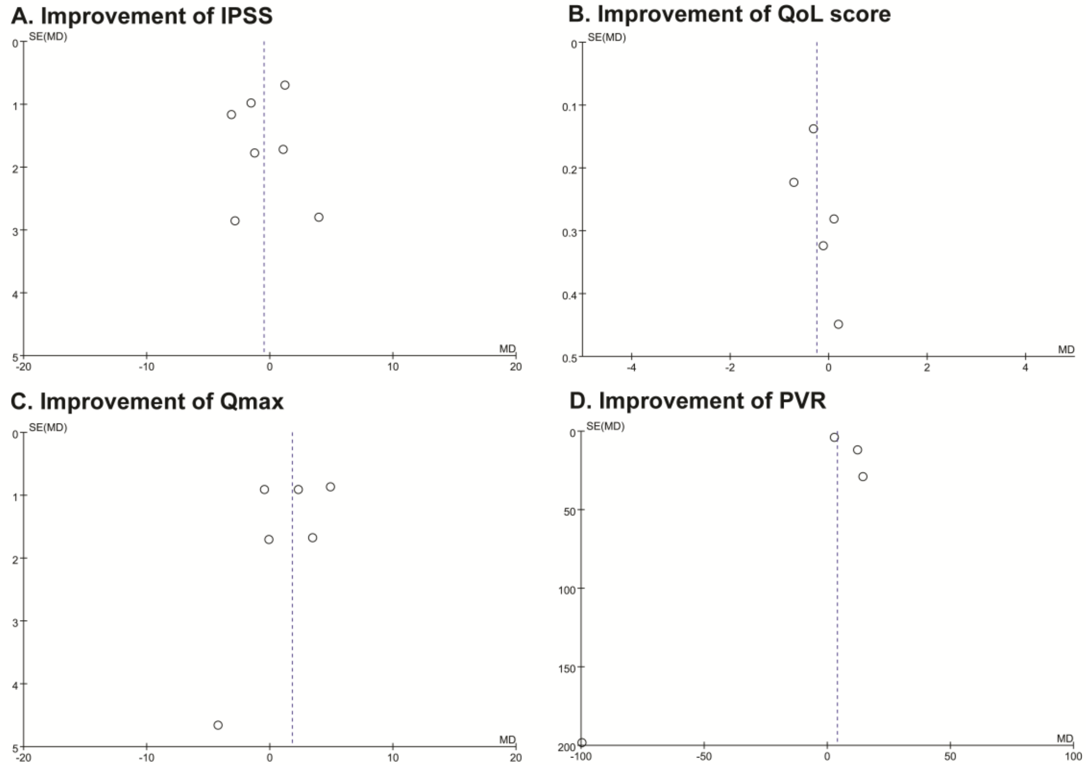


Figure 7. Funnel graphs of the assessment of potential publication bias in studies of comparing improvement of outcome parameters after the transurethral surgery with or without detrusor overactivity (DO)

Table 1. Main characteristics of the eligible studies

| Study | Year | Country | Recruitment period | Study design | Total study population | Type of surgery | Standards of BOO | Cut-off | Standards of DUA | Cut-off | Standards of DO | Cut-off | Quality Assessment (0-24)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Schäfer [26] | 1989 | Germany | NA | Non-randomized prospective | 47 | TURP | $P_{muo}$ | > 40 | NA | - | NA | - | 16 |
| Gormley [27] | 1993 | Canada | NA | Non-randomized prospective | 12 | TURP | URA | > 29 | NA | - | IDC | positive | 17 |
| De la Rosette [28] | 1996 | Multination | 1993-NA | Non-randomized prospective | 120 | TUMT | Lin PURR | ≥ grade 4 | NA | - | NA | - | 18 |
| Ignjatovic [29] | 1997 | Yugoslavia | NA | retrospective | 48 | TURP | Lin PURR | ≥ grade 3 | NA | - | IDC | positive | 16 |
| Witjes [17] | 1997 | Multination | 1992-NA | Non-randomized prospective | 487 | TURP/ PVP/ TUMT | Lin PURR | ≥ grade 4 | NA | - | NA | - | 18 |
| Javlé [30] | 1998 | England | NA | Non-randomized prospective | 55 | TURP | BOOI | > 40 | BCI | < 100 | NA | - | 17 |
| Dahlin [31] | 1999 | Norway | 1995-1996 | retrospective | 49 | ILC | Lin PURR | ≥ grade 4 | NA | - | NA | - | 16 |
| Gotoh [32] | 1999 | Japan | NA | retrospective | 74 | TURP | Lin PURR | ≥ grade 3 | BCI | < 100 | NA | - | 15 |
| Machino [33] | 2002 | Japan | 1992-1999 | retrospective | 62 | TURP | BOOI | > 40 | NA | - | IDC | ≥ 15 $cmH_2O$ | 14 |
| Porru [34] | 2002 | Italy | NA | retrospective | 45 | TURP | Lin PURR | ≥ grade 3 | NA | - | NA | - | 15 |
| Hakenberg [35] | 2003 | Multination | NA | Non-randomized prospective | 95 | TURP | BOOI | > 40 | NA | - | NA | - | 16 |
| Van Venrooij [36] | 2003 | Netherlands | 1996-2002 | Non-randomized prospective | 132 | TURP | BOOI | > 40 | NA | - | NA | - | 17 |
| Monoski [37] | 2006 | USA | 2002-2004 | retrospective | 40 | PVP | $P_{det}$ | > 40 | $P_{det}Q_{max}$/ $Q_{max}$ | < 30 $cmH_2O$/ < 12 mL/sec | IDC | positive | 14 |
| Seki [38] | 2006 | Japan | 1993-2001 | retrospective | 190 | TURP | Lin | ≥ grade | BCI | < 100 | IDC | positive | 14 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | PURR | 3 | | | | | |
| Tanaka [39] | 2006 | Japan | 1995–1997 | retrospective | 92 | TURP | Lin PURR | ≥ grade 4 | BCI | < 100 | IDC | positive | 18 |
| Vesely [16] | 2006 | Sweden | NA | retrospective | 231 | TURP/ TUMT | DAMPF | > 65 | NA | – | NA | – | 14 |
| Paick [9] | 2007 | Korea | NA | retrospective | 68 | PVP | BOOI | > 40 | BCI | < 100 | IDC | positive | 15 |
| Han [40] | 2008 | Korea | NA | retrospective | 71 | TURP | BOOI | > 40 | BCI | < 100 | NA | – | 14 |
| Cho [41] | 2010 | Korea | 2006–2007 | retrospective | 149 | PVP | BOOI | > 40 | NA | – | IDC | positive | 15 |
| Masumori [10] | 2010 | Japan | 1995–1997 | retrospective | 92 | TURP | Lin PURR | ≥ grade 2 | BCI | < 100 | IDC | positive | 14 |
| Oh [42] | 2010 | Korea | 2007–2009 | retrospective | 134 | TURP | BOOI | ≥ 40 | NA | – | IDC | positive | 16 |
| Min [43] | 2013 | Korea | 2006–2011 | retrospective | 285 | TURP | BOOI | > 40 | BCI | < 100 | NA | – | 18 |

BOO, bladder outlet obstruction; DUA, detrusor underactivity; DO, Detrusor overactivity; NA, not available; TURP, transurethral prostatectomy; Pmuo, minimal urethral opening pressure; URA, urethral resistance factor; IDC, involuntary detrusor contraction; TUMT, transurethral microwave thermotherapy; Lin PURR, linear passive urethral resistance relation; BOOI, BOO index; BCI, bladder contractility index; ILC, interstitial laser coagulation; DAMPF, Detrusor Mean Lin PURR Factor;

*Evaluated using Methodological Index for Non-Randomized Studies (MINORS) [18]

Table 2. Patient characteristics

| Study | No. of Analyzed patients | Median age, range (or ± SD) (yr) | Type of surgery | Time of outcome evaluation (months) | Compared outcome parameters | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Symptom score | QoL score | $Q_{max}$ (mL/sec) | PVR (mL) |
| Schäfer [26] | 39 | NA | TURP | NA | NA | NA | available | NA |
| Gormley [27] | 12 | 80 (mean), 72−90 | TURP | 1.5 | NA | NA | available | NA |
| De la Rosette [28] | 120 | 67.0 (mean), 45−89 | TUMT | 6 | IPSS | NA | available | available |
| Ignjatovic [29] | 48 | NA | TURP | 6 | IPSS | NA | NA | NA |
| Witjes (TURP) [17] | 87 | 68.6 (mean), (±8.1) | TURP | 6 | Frimodt−Møller score | NA | available | available |
| Witjes (Laser) [17] | 83 | 64.7 (mean), (±7.0) | PVP | 6 | IPSS | NA | available | available |
| Witjes (TUMT) [17] | 136 | 66.7 (mean), (±8.3) | TUMT | 6 | IPSS | NA | available | available |
| Javlé [30] | 53 (BOO)/ 50 (DUA) | 68.5 (mean), 55−85 | TURP | 3 | IPSS | NA | available | available |
| Dahlin [31] | 24 | 49, 52−80 | ILC | 6 | IPSS | NA | available | NA |
| Gotoh [32] | 74 | 73 (mean), 50−86 | TURP | 1.5−2 | NA | NA | available | available |
| Machino [33] | 62 | 70.3(mean), (±5.4) | TURP | 3 | IPSS | IPSS−QoL | available | available |
| Porru [34] | 45 | 66.8 (mean), 52−81 | TURP | 3−6 | IPSS | IPSS−QoL | available | available |
| Hakenberg [35] | 76 | 74.29 (mean), 46−88 | TURP | 3 | IPSS | NA | available | NA |
| Van Venrooij [36] | 93 | 65.5 (mean), (±4.1) | TURP | 6 | IPSS | IPSS−QoL | available | NA |
| Monoski [37] | 25 | NA | PVP | 1, 3, 6, 12 | IPSS | NA | available | available |
| Seki [38] | 190 | 71.3 (mean), (±7.1) | TURP | 3, 12 | IPSS | IPSS−QoL | available | NA |
| Tanaka [39] | 92 | 69.7 (mean), 54−87 | TURP | 3 | IPSS | IPSS−QoL | available | available |
| Vesely (TURP) [16] | 80 | 68.1 (mean), (±7.9) | TURP | 24, 96 | IPSS | IPSS−QoL | available | NA |
| Vesely (TUMT) [16] | 102 | 67.9 (mean), (±8.4) | TUMT | 24, 96 | IPSS | IPSS−QoL | available | NA |
| Paick [9] | 68 | 68.5, 53−86 | PVP | 6−21, 9 (median) | IPSS | IPSS−QoL | available | available |
| Han [40] | 71 | 68.2 (mean), 46−88 | TURP | 12−55, 19 (median) | IPSS | IPSS−QoL | available | available |
| Cho [41] | 149 | 66, 62−71 (IQR) | PVP | 1, 3, 6, 12 | IPSS | IPSS−QoL | available | available |
| Masumori [10] | 34 | NA | TURP | 3, 36, 84, 144 | IPSS | IPSS−QoL | NA | NA |
| Oh [42] | 134 | 69.9 (mean), (±7.5) | TURP | 12 | IPSS | NA | available | available |
| Min [43] | 285 | 69.3 (mean), (±8.2) | TURP | ≥ 3 | IPSS | IPSS−QoL | available | available |

SD, standard deviation; QoL, quality of life; Qmax, maxim flow rate on uroflowmetry; PVR, post−void residual; NA, not available; TURP, transurethral prostatectomy; TUMT, transurethral microwave thermotherapy; IPSS, International Prostate Symptom Score; PVP, photoselective vaporization of the prostate; BOO, bladder outlet obstruction; DUA, detrusor underactivity; ILC, interstitial laser coagulation; IQR, interquartile range;

Table 3. Related matters regarding processing the outcome parameters for data synthesis

| Study | Related matters | Data processing | Notes |
|---|---|---|---|
| Schäfer [26] | Sub-grouped in three, by the standards of $P_{muo}$ < 25cm $H_2O$, 25-40cm $H_2O$, and > 40cm$H_2O$ | Outcome parameters of two groups ($P_{muo}$ <25cm $H_2O$ and 25-40cm $H_2O$) were integrated using pooled mean, and standard deviation (SD) [19] | - |
| Gormley [27] | Presented pre- and post-TURP $Q_{max}$ of whole subject | Calculated mean ⊿$Q_{max}$ and SD using presented parameters | - |
| De la Rosette [28] | Sub-grouped in three, by the standards of Lin PURR grade 0-1, 2-3, and 4-6 | Outcome parameters of two groups (Lin PURR grade 0-1, and 2-3) were integrated using pooled mean, and SD | - |
| Ignjatovic [29] | ⊿IPSS was presented as median value with interquartile range (IQR) | Mean and SD were estimated using presented median and IQR [19] | - |
| Witjes [17] | Symptom score of TURP subgroup was presented using Frimodt-Møller score | Excluded from the data synthesis | Outcomes of each modality (TURP/PVP/TUMT) were integrated separately. |
| | ⊿IPSS was presented as median value with range | Mean and SD were estimated using presented median and range [19] | |
| | Each sub-group was categorized in three, by the standards of Lin PURR grade 0-1, 2-3, and 4-6 | Outcome parameters of two groups (Lin PURR grade 0-1, and 2-3) were integrated using pooled mean, and SD | |
| Javlé [30] | Outcome parameters were presented as mean value with standard error (SE) | SD were estimated using presented SE and sample size [19] | - |
| | Sub-grouped in three, by the standards of BOOI < 20 (unobstructed), 20-40 (equivocal), and > 40 (obstructed) | Outcome parameters of two groups (unobstructed and equivocal) were integrated using pooled mean, and SD | |
| Døhlin [31] | Outcome parameters were presented as median value with 95% confidence interval (CI) | Mean and SD were estimated using presented sample size and 95% CI | - |
| Gotoh [32] | Sub-grouped in three as group A (obstructed and normal detrusor), group B (obstructed and weak detrusor), group C (unobstructed and weak detrusor) | Outcome parameters of group A and B were integrated for the data synthesis of BOO, and group B and C were integrated the data synthesis of DUA | - |
| Machino [33] | Presented pre- and post-TURP IPSS, IPSS-QoL, $Q_{max}$, and PVR with SD of each group | Estimated the mean ⊿ IPSS, ⊿ IPSS-QoL, ⊿$Q_{max}$, and ⊿PVR with their SD using pre- and post-TURP values [20] | - |

| | | | |
|---|---|---|---|
| Porru [34] | Presented pre- and post-TURP IPSS, IPSS-QoL, $Q_{max}$, and PVR with SD of each group | Estimated the mean ⊿ IPSS, ⊿ IPSS-QoL, ⊿ $Q_{max}$, and ⊿ PVR with their SD using pre- and post-TURP values | - |
| Hakenberg [35] | Outcome parameters were presented as mean value with standard error (SE) | SD were estimated using presented SE and sample size | - |
| | Sub-grouped in three, by the standards of BOOI < 20 (unobstructed), 20-40 (equivocal), and > 40 (obstructed) | Outcome parameters of two groups (unobstructed and equivocal) were integrated using pooled mean, and SD | |
| Van Venrooij [36] | ⊿IPSS, ⊿IPSS-QoL, and ⊿ $Q_{max}$ were presented as median value with IQR | Mean and SD were estimated using presented median and IQR | - |
| Monoski [37] | Presented pre- and post-PVP IPSS, $Q_{max}$, and PVR with SD of each group | Estimated the mean ⊿ IPSS, ⊿ $Q_{max}$, and ⊿ PVR with their SD using pre- and post-PVP values | - |
| | Presented 1,3,6, and 12 months postoperative data | Utilized the 1 month postoperative data due to the largest population | |
| | Only one preoperative $Q_{max}$ value of DUA positive group is available | Excluded from data integration due to unestimatable SD | |
| Seki [38] | Presented pre- and post-TURP IPSS, IPSS-QoL, and $Q_{max}$, with SD of each group | Estimated the mean ⊿ IPSS, ⊿ IPSS-QoL, and ⊿ $Q_{max}$ with their SD using pre- and post-TURP values | - |
| | Presented 3 and 12 months postoperative data | Utilized the 3 month postoperative data due to larger population | |
| Tanaka [39] | Presented pre- and post-PVP IPSS, IPSS-QoL, $Q_{max}$, and PVR with SD of each group | Estimated the mean ⊿ IPSS, ⊿ IPSS-QoL, ⊿ $Q_{max}$, and ⊿ PVR with their SD using pre- and post-TURP values | - |
| | Sub-grouped in three, by the standards of Lin PURR grade 0-1, 2-3, and 4-6 | Outcome parameters of two groups (Lin PURR grade 0-1, and 2-3) were integrated using pooled mean, and SD | |
| Vesely [16] | Presented pre- and post-treatment IPSS, IPSS-QoL, and $Q_{max}$ with SD of each group | Estimated the mean ⊿ IPSS, ⊿ IPSS-QoL, and ⊿ $Q_{max}$ with their SD using pre- and post-treatment values | Outcomes of each modality (TURP/TUMT) were integrated separately. |
| | Sub-grouped in three, by the standards of DAMPF < 43 (minor), 43-65 (moderate), and > 40cm$H_2O$ (severe) | Outcome parameters of two groups (minor and moderate) were integrated using pooled mean, and SD | |
| | Presented 3 and 12 months | | |

| | | | |
|---|---|---|---|
| | postoperative data | Utilized the 3 month postoperative data due to larger population | |
| Paick [9] | ⊿IPSS and ⊿$Q_{max}$ was presented as median value with IQR<br>Pre- and post-PVP IPSS-QoL, and PVR of each group were presented as median with IQR | Mean and SD were estimated using presented median and IQR<br>Estimated the mean⊿ IPSS-QoL and ⊿PVR with their SD using pre- and post-PVP values | – |
| Han [40] | Presented pre- and post-TURP IPSS, IPSS-QoL, and $Q_{max}$ with SD of each group | Estimated the mean ⊿ IPSS, ⊿ IPSS-QoL, and ⊿$Q_{max}$ with their SD using pre- and post-TURP values | – |
| Cho [41] | ⊿IPSS, ⊿IPSS-QoL, ⊿$Q_{max}$, and ⊿PVR were presented as median value with IQR<br>Presented 1,3,6, and 12 months postoperative data | Mean and SD were estimated using presented median and IQR<br>Utilized the 1 month postoperative data due to the largest population | – |
| Masumori [10] | Presented pre- and post-TURP IPSS, and IPSS-QoL with SD of each group<br>Presented 3, 36, 72, and 144 months postoperative data | Estimated the mean ⊿ IPSS and ⊿ IPSS-QoL with their SD using pre- and post-TURP values<br>Utilized the 3 month postoperative data due to larger population | – |
| Oh [42] | IPSS-storage and IPSS-emptying were presented separately<br>Presented pre- and post-TURP IPSS, $Q_{max}$, and PVR with SD of each group | IPSS-total was calculated using pooled mean, and SD<br>Estimated the mean ⊿ IPSS, ⊿$Q_{max}$, and ⊿PVR with their SD using pre- and post-TURP values | – |
| Min [43] | Sub-grouped in three, by the standards of BOOI < 20 (unobstructed), 20-40 (equivocal), and > 40 (obstructed) | Outcome parameters of two groups (unobstructed and equivocal) were integrated using pooled mean, and SD | – |

Pmuo, minimal urethral opening pressure; Lin PURR, linear passive urethral resistance relation; TURP, transurethral prostatectomy; Qmax, maximal flow rate on uroflowmetry; PVP, photoselective vaporization of the prostate; TUMT, transurethral microwave thermotherapy; IPSS, International Prostate Symptom Score; QoL, quality of life; PVR, post-void residual; PVP, photoselective vaporization of the prostate; DUA, detrusor underactivity; DAMPF, Detrusor Mean Lin PURR Factor; IPSS-storage, sum of IPSS question 2, 4, and 7; IPSS-emptying, sum of IPSS question 1, 3, 5, and 6; IPSS-total, sum of total IPSS questions

Table 4. Subgroup analysis in patients underwent conventional transurethral resection of the prostate (TURP)

| | No. of included articles | Included studies | No. of participants | Pooled MD (95% CI) | $I^2$ | $x^2$ (p value) |
|---|---|---|---|---|---|---|
| BOO positive vs. BOO negative | | | | | | |
| Improvement of IPSS | 13 | [10,16,29,30,33−36,38−40,42,43] | 1261 | 4.30 (2.25−6.35) | 86% | 84.05 (<0.01) |
| Improvement of IPSS−QoL | 9 | [16,33,34,36,38−40,42,43] | 950 | 0.59 (0.11−1.07) | 85% | 52.58 (<0.01) |
| Improvement of $Q_{max}$ | 15 | [16,17,26,27,30,32−36,38−40,42,43] | 1387 | 4.57 (2.47−6.67) | 90% | 137.14 (<0.01) |
| Improvement of PVR | 9 | [17,30,32−34,39,40,42,43] | 880 | 33.30 (24.38−42.23) | 1% | 8.06 (0.43) |
| DUA positive vs. DUA negative | | | | | | |
| Improvement of IPSS | 4 | [10,30,39,40] | 247 | −5.65 (−7.76−−3.54) | 25% | 3.98 (0.26) |
| Improvement of IPSS−QoL | 3 | [10,39,40] | 197 | −0.52 (−0.91−−0.13) | 0% | 1.04 (0.59) |
| Improvement of $Q_{max}$ | 4 | [30,32,39,40] | 287 | −4.03 (−5.41−−2.66) | 0% | 2.78 (0.43) |
| Improvement of PVR | 4 | [30,32,39,40] | 287 | −15.61 (−29.43−−1.80) | 0% | 1.51 (0.68) |
| DO positive vs. DO negative | | | | | | |
| Improvement of IPSS | 4 | [10,33,38,39] | 376 | −0.39 (−3.18−2.40) | 62% | 7.89 (0.05) |
| Improvement of IPSS−QoL | 4 | [10,33,38,39] | 376 | −0.19 (−0.64−0.26) | 56% | 6.80 (0.08) |
| Improvement of $Q_{max}$ | 3 | [33,38,39] | 338 | 0.75 (−1.56−3.06) | 53% | 4.25 (0.12) |
| Improvement of PVR | 2 | [33,39] | 131 | 12.65 (−9.68−34.98) | 0% | 0.01 (0.94) |

MD, mean difference; CI, confidence interval; BOO, bladder outlet obstruction; IPSS, International Prostate Symptom Score; QoL, quality of life; Qmax, maximal flow rate on uroflowmetry; PVR, post−void residual; DUA, detrusor underactivity; DO, detrusor overacitivity

Table 5. Sensitivity analysis of BOO comparisons by the two dominant criteria for BOO diagnosis (BOO index [BOOI] > 40 and linear passive urethral resistance relation [lin PURR] grade ≥ 2, 3, or 4)

| | No. of included articles | Included studies | No. of participants | Pooled MD (95% CI) | $I^2$ | $x^2$ (p value) |
|---|---|---|---|---|---|---|
| Diagnosis by BOOI | | | | | | |
| Improvement of IPSS | 7 | [30,33,35,36,40,42,43] | 772 | 3.29 (1.51–5.06) | 70% | 19.89 (<0.01) |
| Improvement of IPSS–QoL | 4 | [33,36,40,43] | 509 | 0.21 (−0.21–0.64) | 67% | 9.02 (0.03) |
| Improvement of $Q_{max}$ | 7 | [30,33,35,36,40,42,43] | 768 | 3.78 (2.60–4.95) | 45% | 10.87 (0.09) |
| Improvement of PVR | 5 | [30,33,40,42,43] | 582 | 29.24 (17.50–40.98) | 0% | 1.61 (0.81) |
| Diagnosis by Lin PURR | | | | | | |
| Improvement of IPSS | 8 | [10,17,28,29,31,34,38,39] | 772 | 3.73 (0.05–7.40) | 90% | 82.50 (<0.01) |
| Improvement of IPSS–QoL | 4 | [10,34,38,39] | 361 | 1.19 (0.03–2.35) | 92% | 38.52 (<0.01) |
| Improvement of $Q_{max}$ | 7 | [17,28,31,32,34,38,39] | 851 | 2.84 (1.30–4.38) | 68% | 25.25 (<0.01) |
| Improvement of PVR | 5 | [17,28,32,34,39] | 637 | 34.28 (17.28–51.28) | 41% | 10.14 (0.12) |

MD, mean difference; CI, confidence interval; BOO, bladder outlet obstruction; IPSS, International Prostate Symptom Score; QoL, quality of life; Qmax, maximal flow rate on uroflowmetry; PVR, post−void residual; DUA, detrusor underactivity; DO, detrusor overacitivity;

Appendix 1. Detailed query settings for search strategy

| Search | Query |
|---|---|
| #1 | Search "Prostatic Hyperplasia"[Mesh] |
| #2 | Search benign prostat* |
| #3 | Search lower urinary tract symptom |
| #4 | Search LUTS |
| #5 | Search (#3 or #4) |
| #6 | Search male |
| #7 | Search female |
| #8 | Search (#6 not #7) |
| #9 | Search man |
| #10 | Search woman |
| #11 | Search (#9 not #10) |
| #12 | Search (#8 or #11) |
| #13 | Search (#5 and #12) |
| #14 | Search (#1 or #2 or #13) |
| #15 | Search "Transurethral Resection of Prostate"[Mesh] |
| #16 | Search transurethral resection* |
| #17 | Search transurethral* |
| #18 | Search TURP |
| #19 | Search TUI* |
| #20 | Search (#15 or #16 or #17 or #18 or #19) |
| #21 | Search "laser" |
| #22 | Search holmium |
| #23 | Search thallium |
| #24 | Search potassium* titanyl* phosphate |
| #25 | Search KTP |
| #26 | Search Nd* YAG |
| #27 | Search PVP |
| #28 | Search vaporization |
| #29 | Search enucleation |
| #30 | Search HoLEP |
| #31 | Search ablation |
| #32 | Search (#21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30 or #31) |
| #33 | Search (#20 or #32) |
| #34 | Search (#14 and #33) |
| #35 | Search "Urodynamics"[Mesh] |
| #36 | Search urodynamic* |
| #37 | Search pressure* flow* |
| #38 | Search cystometry |
| #39 | Search obstruction |
| #40 | Search underactiv* |
| #41 | Search acontractile* |
| #42 | Search impaired detrusor* |
| #43 | Search (#35 or #36 or #37 or #38 or #39 or #40 or #41 or #42) |
| #44 | Search (#34 and #44) |

Presented as query form of Pubmed
Core logics of search queries were not different in other database searching.

# 국문 초록

**서론:** 수술적 치료를 고려하는 전립선비대증 환자에서 술 전 요역동학 검사의 진단적 가치에 대해 알아보고자 하였다.

**방법:** Pubmed, Embase, 및 Cochrane Library database 에서 1991 년 1 월부터 2014 년 6 월까지의 관련 연구 문헌들을 계통적으로 고찰 후 메타분석을 시행하였다.

**결과:** 총 22 개의 연구가 계통적 고찰 요건을 충족하여 선별되었다. 선별된 연구의 총 대상자 수는 2,578 명이었고, 연구당 중앙값 83 명 (range: 12−437) 환자가 포함되어 있었다. 22 편의 연구 중 15 편에서 통상적인 경요도전립선절제술을 시행하였으며, 7 에서 다른 방법의 수술을 시행하였다. 요역동학검사에서 방광출구폐색 소견이 있는 환자에서 수술 후 국제전립선증상점수 (pooled MD, 3.48; 95% confidence interval [CI], 1.72−5.24; 분석연구, 16 편; 대상자 수, 1,726 명), 삶의질 점수 (pooled MD, 0.56; 95% CI, 0.14−1.02; 분석연구, 9 편; 대상자 수, 1,052 명), 최대요속 (pooled MD, 3.86; 95% CI, 2.17−5.54; 분석연구, 17 편; 대상자 수, 1,852 명), 및 잔뇨량 (pooled MD, 32.46; 95% CI, 23.34−41.58; 분석연구, 10 편; 대상자 수, 1,219 명)의 호전 정도가 방광출구폐색 소견이 없는 환자에 비해 유의하게 증가되었다. 배뇨근저활동성 소견이 있는 환자에서는 수술 후 국제전립선증상점수 (pooled MD, −5.83; 95% CI,

−7.18−−4.49; 분석연구, 6 편; 대상자 수, 340 명) 및 최대요속 (pooled MD, −3.86; 95% CI, −4.93−−2.80; 분석연구, 5 편; 대상자 수, 355 명)의 호전 정도가 배뇨근저활동성 소견이 없는 환자에 비해 유의하게 감소하였으나, 삶의질 점수 및 잔뇨량의 호전 정도는 배뇨근저활동성 소견의 유무에 상관이 없었다. 반면 배뇨근과활동성 소견 유무는 수술 후 호전의 정도와 관련된 모든 지표에 영향을 미치지 않았다. 일부 연구에서 연구간 이질성을 보이기는 하였지만, 메타분석에 포함된 선별 연구들에서 출판편향 등의 명확한 증거는 없었다.

**결론:** 본 메타분석 결과, 수술 전 요역동학검사에서 방광출구폐색 소견이 있는 경우, 수술적 치료 성적에 관련된 모든 지표에서 증상 호전의 정도가 유의하게 증가하는 것을 확인할 수 있었다. 배뇨근저활동성은 국제전립선증상점수와 최대요속의 호전 정도의 유의한 감소와 상관 있었다. 하지만 배뇨근과활동성은 수술 성적과 연관관계가 없었다. 수술 전 요역동학검사는 전립선비대증 환자에서 수술적 치료를 고려할 때, 수술 성적을 예측하는데 도움을 주는 유용한 검사법으로 생각된다.

**주요어 : 전립선비대증, 경요도수술, 수술 성적, 요역동학 검사, 방광출구폐색, 배뇨근저활동성, 배뇨근과활동성**

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